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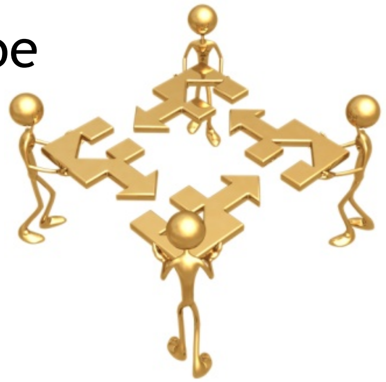
TOWARDS MORE SUSTAINABLE AND EFFICIENT BIOFUELS PRODUCTION – USE OF PERVAPORATION IN PRODUCT RECOVERY AND PURIFICATION

1st POKE workshop
11.-12.6.2013, Stockholm

Johanna Niemistö
Mass and Heat Transfer Process Laboratory
Department of Process and Environmental Engineering

MOTIVATION

- Biobutanol is a potential transportation fuel having better fuel properties than ethanol
- There is still some challenges to overcome before a competitive industrial production process is available
- Sustainability issues (all three aspects) are needed to be taken into consideration in process developments
- Evaluation of sustainability needs harmonization and common criteria



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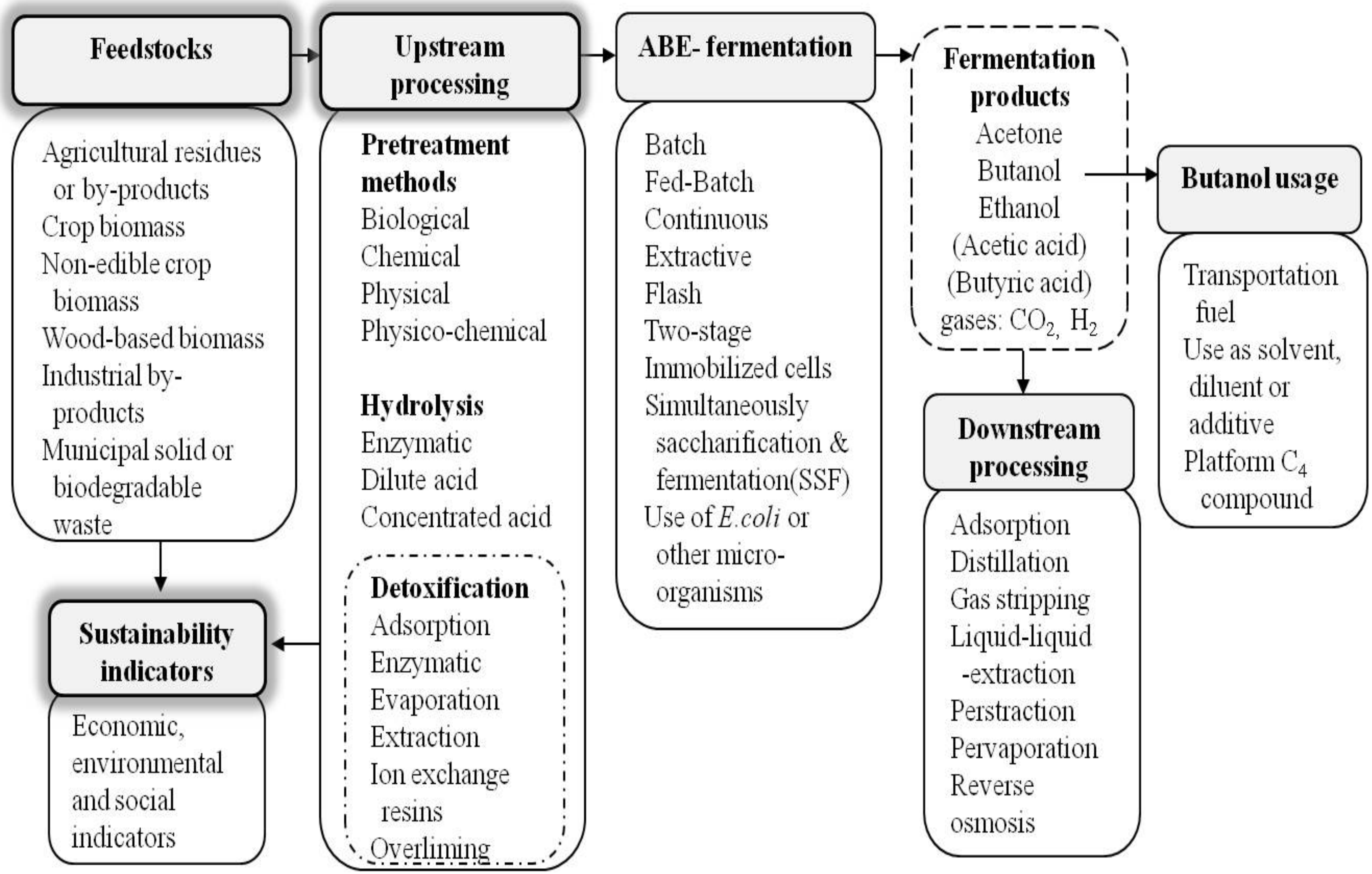
The aims of the research:

1) to obtain new knowledge of the transportation biofuel (biobutanol and bioethanol) production processes utilizing different kinds of biomasses

2) to develop more sustainable and more efficient production steps for these production processes

Towards more sustainable and efficient biofuels production – use of pervaporation in product recovery and purification

BIOFUEL/BIOBUTANOL PRODUCTION

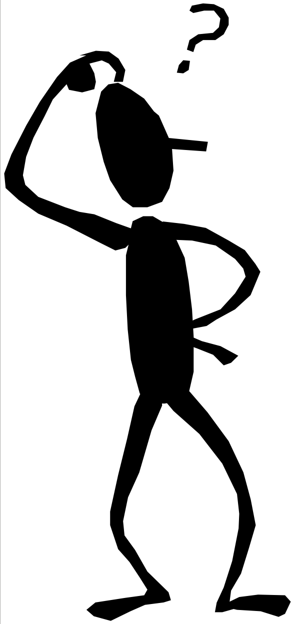


Niemistö J, Saavalainen P, Isomäki R, Kolli T, Huuhtanen M & Keiski RL (2013), Biobutanol production from biomass.
In: Gupta VK & Tuohy MG (Eds) Biofuel Technologies: Recent developments. Berlin-Heidelberg, Springer-Verlag: 443-470.

CHALLENGES OF THE PRODUCTION

- Cost of substrates and unit processes

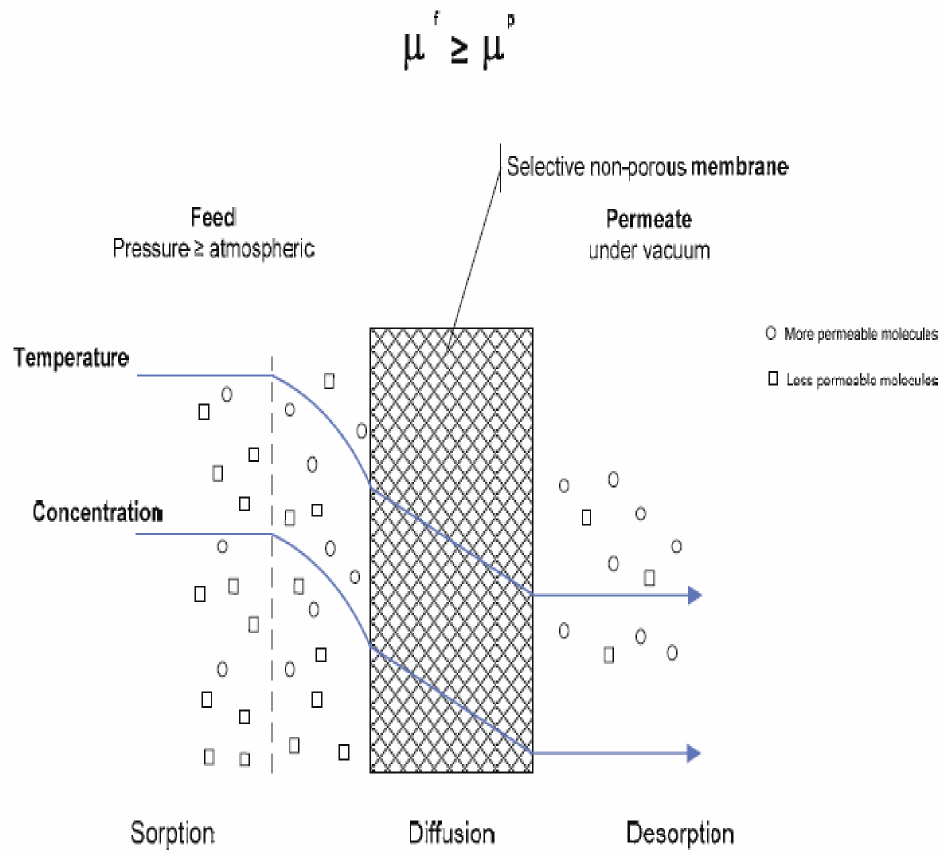
- Product inhibition
  - Low product concentrations



- Complicated process chain: up- and downstream steps affect also the fermentation step
  → Process design should be done carefully

PERVAPORATION

- Selective transport of component(s) through the membrane
  - Difference in chemical potential as the driving force, pressure driven mass transfer
- Only permeate is evaporated → energy savings
- Mild processing conditions, can be combined together with a fermentation unit



Schematic diagram of the principle of the pervaporation
(García 2009, Reclamation of VOCs, n-butanol and dicholormethane, from sodium chloride containing mixtures by pervaporation. Towards efficient use of resources in the chemical industry. PhD Thesis, University of Oulu).

BUTANOL RECOVERY

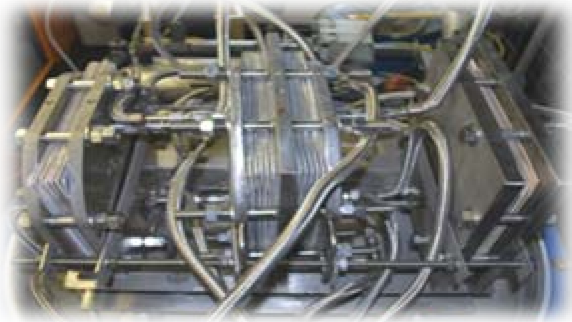
- PDMS–PAN composite membrane
- Various binary, ternary and quaternary water–acetone-butanol-ethanol(ABE)-solutions were tested at 42°C
- Permeation fluxes (J_i), membrane permeances (P_i/l), separation factors (α_i) and pervaporation separation indices (PSI) were determined

- ➢ Membrane permselectivity followed the order of acetone≈butanol>ethanol
- ➢ Permeation of n-butanol is preferable in solutions containing several organic compounds, indicating that the tested PDMS-membrane has a potential to be used in the ABE fermentation process.

Niemistö J., Kujawski W., Keiski R.L. (2013), Pervaporation performance of composite poly(dimethyl siloxane) membrane for butanol recovery from model solutions. Journal of Membrane Science, 434:55–64.

DEHYDRATION OF BIOETHANOL

- Feed pretreatment by charcoal filtration
  - An efficient and up-scalable method
- Pervap(r) based, hydrophilic crosslinked polyvinyl alcohol (PVA) composite membranes at 98 °



Run	Feed EtOH conc. [wt%]	Final EtOH conc. [wt%]	Feed [kg]	Operation time [h]	Membrane area [m^2]	Notifications
1	90.0	99.6	70	28	2	Retentate was circulated continuously back to the feed tank.
2	87.8	99.6	70	44 (10+18+16)	2	Both permeate and retentate were circulated back to the feed tank during the steady state stage.
3	85.1	99.6	35	18	1	Membrane 1
4	84.9	99.6	35	18	1	Membrane 2

- Permeation fluxes (J_i), membrane permeances (PM_i), separation factors (α_i) and pervaporation separation indices (PSI) were determined

Niemistö J., Pasanen A., Hirvelä K., Myllykoski L., Muurinen E., Keiski R.L. (2013), Pilot study of bioethanol dehydration with polyvinyl alcohol membranes. Journal of Membrane Science, 447:119–127.

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Biofuel/biobutanol production

Niemistö J., Saavalainen P., Isomäki R., Kolli T., Huuhtanen M., Keiski R.L. (2013) Biobutanol production from biomass. In: Gupta V.K., Tuohy M.G. (eds). Biofuel Technologies: Recent developments. Springer. Springer-Verlag, Berlin-Heidelberg (2013), Chapter 17. pp. 443-470.

García V., Päkkilä J., Ojamo H., Muurinen E., Keiski R.L. (2011). Challenges in biobutanol production: How to improve the efficiency? Renewable and Sustainable Energy Reviews 15(2011), pp. 964 - 980.

Towards production of more sustainable and efficient biofuels – use of pervaporation in product recovery and purification

Pervaporation studies

Niemistö J., Kujawski W., Keiski R.L., Pervaporation performance of composite poly(dimethyl siloxane) membrane for butanol recovery from model solutions. Journal of Membrane Science, 434 (2013) 55–64.

Niemistö J., Pasanen A., Hirvelä K., Myllykoski L., Muurinen E., Keiski R.L. (2013), Pilot study of bioethanol dehydration with polyvinyl acetate membranes. (Manuscript, submitted to Journal of Membrane Science in April 2013).

Sustainability

Niemistö J., Saavalainen P., Pongrácz E., Keiski R.L. (2013), Biobutanol as a potential sustainable biofuel - Assessment of lignocellulosic and waste-based feedstocks. Journal of Sustainable Development of Energy, Water and Environment Systems 1(2) 1–19.

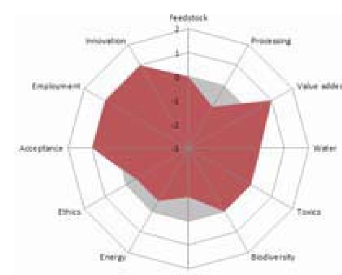
SUSTAINABILITY ASSESSMENT OF LIGNOCELLULOSIC AND WASTE-BASED FEEDSTOCKS

Indicators chosen for biobutanol feedstock evaluation:

Economic	Environmental	Social
Feedstock price	Biodiversity and land use change	Customer acceptance and social dialog
Processing costs	Hazardous and toxic material usage	Ethicality and competing demand of raw materials
Value added	Emissions (e.g. GHG)	Employment effects
	Energy	Health and safety issues
	Wastes vs. by-products	Innovation and education potential
	Water consumption	

Crop biomass: corn

Non-edible crop: straw

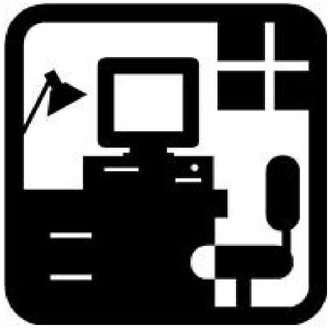


Food by-product: whey

Wood-based biomass: saw dust

Niemistö J., Saavalainen P., Pongrácz E. & Keiski R.L.(2013), Biobutanol as a potential sustainable biofuel - Assessment of lignocellulosic and waste-based feedstocks. Journal of Sustainable Development of Energy, Water and Environment Systems 1(2) 1-19.

Status of the PhD thesis



- Last part of the thesis process is going on:
  - Finalizing of the last publication
  - Writing of the compilation part
- Academic dissertation will be at the end of year 2013/in the beginning of 2014.

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THANK YOU FOR YOUR ATTENTION!

Acknowledgements:

- The Doctoral Program in Energy Efficiency and Systems (financed the by the Academy of Finland)
- The Academy of Finland (Project no. 124510, New, innovative sustainable transportation fuels for mobile applications: from biocomponents to flexible liquid fuels (SUSFUFLEX))
- The Finnish Funding Agency for Technology and Innovation (Tekes),(Decision number 40313/31/2009: Intensification of bioprocess chains (FERMET))
- Sulzer Chemtech Ltd, St1 Biofuels Oy